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Effects of Research and Development Subsidies on Research and Development Investment and Firm Performance: Evidence From High-Tech Firms in China

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Abstract

Over the past decade, the Chinese government has actively promoting research and development (R&D) in high-tech industries to foster scientific and technological innovation and address economic slowdown. Against this backdrop, this study explores how the interaction between government R&D subsidies and R&D investment influences the performance of high-tech firms in China. Specifically, it investigates (i) the relationship between government R&D subsidies and firm performance, (ii) the relationship between government R&D subsidies and R&D investment, and (iii) the mediating role of R&D investment in the relationship between government R&D subsidies and firm performance. Analysing 773 listed high-tech firms from 2018 to 2021, this study finds that direct government R&D subsidies and tax incentives do not significantly influence firm performance. However, direct subsidies indirectly reduce firm performance by stimulating R&D investments that are resource-intensive and risky in nature. This mediating effect is not observed in the case of tax incentives. The findings provide insights into enhancing the effectiveness of R&D subsidies in promoting R&D investment and firm performance in high-tech industries.

Keywords: Research and Development, Subsidy, Tax Incentive, Firm Performance

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1.0 Introduction

In the realm of economic globalisation, firms must acquire key technologies to remain competitive in a rapidly evolving market. Research and development (R&D) is widely recognized as a crucial factor in driving firm growth (Brown et al., 2009). Aligned with the SDGs, countries worldwide have committed to increasing R&D investments. Consequently, it is not surprising that global R&D spending has soared to an unprecedented level of nearly 1.7 trillion dollars (UIS, 2020). While developed nations and multinational corporations have historically led R&D investments, emerging economies like China are prioritizing scientific and technological advancement. Data from the National Bureau of Statistics of China (see Figure 1) indicates that China's R&D investment and intensity have steadily risen over the past seven years, with only a slight setback during the COVID-19 pandemic. In 2022, China's total R&D expenditure reached 3,087 billion yuan, reflecting a 10.2% year-on-year increase or an 8.0% rise in real terms. The R&D to GDP ratio climbed to 2.55%, up by 0.12% from the previous year. Additionally, OECD data ranks China second globally in total R&D expenditure, trailing only the US. Regarding growth rate (see Figure 2), China's R&D spending grew at a yearly rate of 12.3% between 2016 and 2021, significantly outpacing developed nations such as the US (7.8%), Japan (1.0%), Germany (3.5%), and South Korea (7.6%) from 2016 to 2020.

China's 14th Five-Year Plan (2021-2025) outlines concrete measures to boost both public and private investment in R&D within science and technology, emphasizing innovation as a central pillar of the country's modernization efforts. However, the significant financial commitments and extended timelines associated with R&D projects create cash flow uncertainty and expose firms to the risk of unsuccessful outcomes, leading to more cautious investment decisions (Beladi et al., 2021). To address these challenges, the Chinese government and affiliated institutions have implemented various R&D subsidies, such as those under the Measures for the Administration of High-tech Enterprise Accreditation. These initiatives aim to provide external financial support, reduce firms' financial constraints on R&D investment, and promote greater participation in R&D activities.

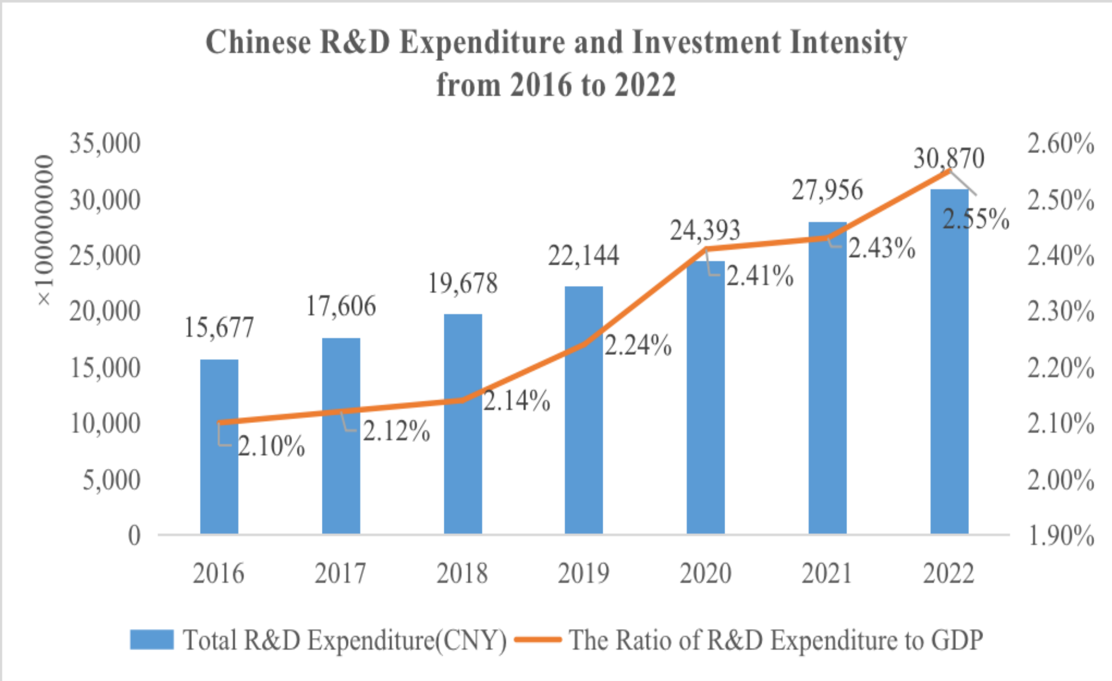

Figure 1: China's R&D Expenditure and Investment Intensity from 2016 to 2022

Source: National Bureau of Statistics of China (National Bureau of Statistics, 2022)

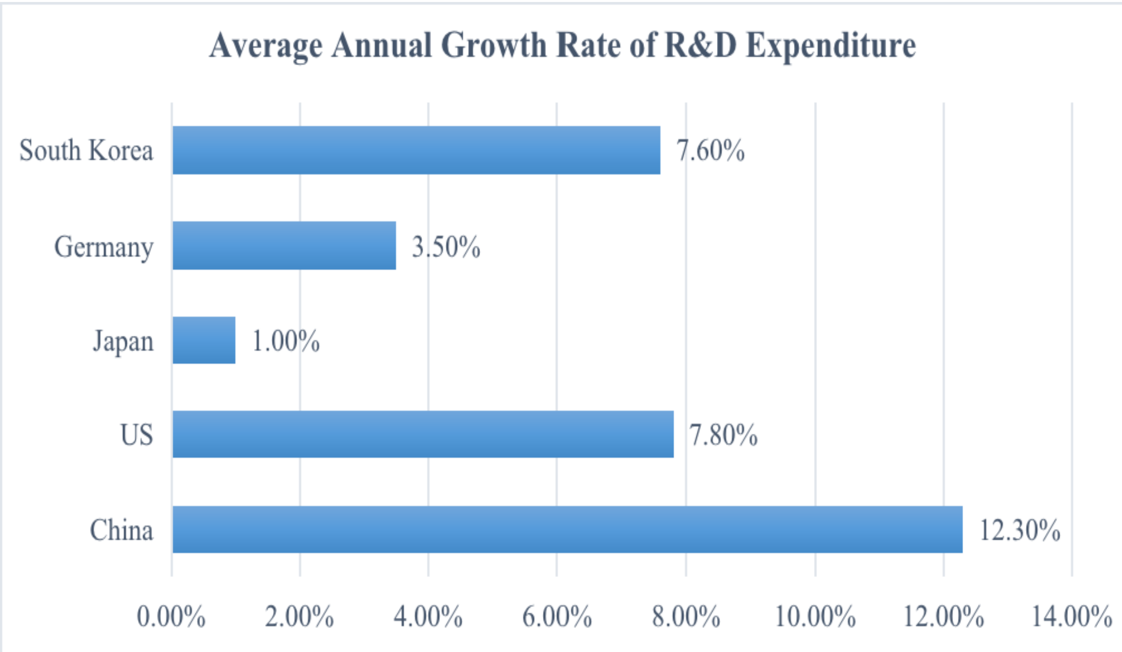

Figure 2: Average Annual Growth Rate of R&D Expenditure in China and Major Developed Countries from 2016 to 2021

Source: OECD Database (OECD, 2023)

Government subsidies enable firms to allocate resources more efficiently, enhancing innovation (Sun et al., 2020). This fosters technological breakthroughs and innovations, which can be transformed into new products, improved production processes, or enhanced intellectual property rights, ultimately strengthening market competitiveness. Ultimately, product competitiveness and productivity improvements driven by innovation translate into better market performance, including increased market share, sales revenue, and profitability (Jin et al., 2018). Theoretically, through this mediating mechanism, R&D subsidies not only promote R&D investment but also drive technological innovation and improve firm performance by ensuring effective R&D implementation. However, this argument remains inconclusive, as some studies have reported that subsidies can have a significantly negative effect (Wang et al., 2021) or a non-linear effect on the financial performance of high-tech firms, specifically those in the new energy vehicle sector (Yu et al., 2020). Although subsidies boost R&D investment, newly developed products may face challenges in market adoption, delaying profitability.

Against this backdrop, this study aims to investigate (i) the effect of government R&D subsidies on firm performance, (ii) the effect of government R&D subsidies on R&D investment, and (iii) the mediating role of R&D investment in the relationship between government R&D subsidies and firm performance in China. This study focuses on high-tech firms listed on the A-Share Indexes and Growth Enterprise Board from 2018 to 2021. Compared to companies in other industries, high-tech companies are inherently more closely connected to R&D due to their ongoing involvement in research, development, and technology commercialization within designated "National Key Supported High-Tech Areas", This motivates high-tech firms towards the creation of core proprietary intellectual property. Conducting research on issues related to R&D subsidy policies in high-tech sectors contributes to the advancement of the theory of R&D subsidies and provides valuable guidance for their implementation in China.

China offers a distinct study context due to notable differences in how countries approach R&D subsidies. In China, R&D support consists of both tax incentives and direct subsidies, with tax incentives being the dominant mechanism. In contrast, countries like Japan and Australia primarily rely on indirect tax incentives, which make up over 80% of their total R&D subsidies. Meanwhile, nations such as South Korea and Austria employ a mix of direct fiscal subsidies and indirect tax incentives, allocating similar expenditure levels to both. On the other hand, the U.S., Russia, and several other countries predominantly use direct financial subsidies, which account for at least 70% of their total R&D support. These variations highlight that multiple factors influence the scale, effectiveness, and selection of subsidy strategies adopted by governments. Thus, directly applying the R&D subsidy models of other countries to China may not be appropriate.

This study contributes to the existing R&D-firm performance literature in three key ways. First, it explores the complex mediating role of R&D investment. Previous research has largely examined individual relationships: between R&D subsidies and firm performance (Alam et al., 2019; Bae et al., 2008; Connolly & Hirschey, 2005); between R&D subsidies and R&D investment (Hong et al., 2015; Howell, 2017); and between R&D investment and firm performance (Ehie & Olibe, 2010; Kothari et al., 2016; Xu et al., 2021). However, these studies have produced mixed results, leaving uncertainty regarding the mediating role of R&D investment in linking R&D subsidies to firm performance. To fill this gap, this study applies the well-established mediating-effect model developed by Wen et al. (2004) to examine the intricate relationships among these three variables within an analytical framework.

This study addresses the limited focus on high-tech firms in the existing literature. While previous studies have explored R&D issues for various types of firms, such as SMEs (Bronzini & Piselli, 2016; Guo et al., 2016; Kang & Park, 2012; Liao & Rice, 2010), renewable energy firms (Lin & Xie, 2023; Zhang & Zhang, 2023), manufacturing firms (Carboni, 2011), and general firms (Akcigit & Kerr, 2018; Alam et al., 2020; Lee, 2011; Wang et al., 2017), this present study differentiates itself by focusing specifically on high-tech firms in China as these firms are renowned for their knowledge-intensive and technology-intensive nature. More importantly, R&D investment research for firms in China is very limited due to data constraints, which only began from the year 2018. Therefore, investigating high-tech firms provides new and explicit evidence regarding the role of R&D in the performance of R&D-intensive firms.

Furthermore, the functional mechanism of direct subsidies and tax incentives is different, and their effects on R&D investments and firm performance remain unknown a priori. Specifically, Hottenrott and Lopes-Bento (2014) found that direct subsidies enhance firms' R&D efforts and innovation performance, while Lee (2011) discovered that subsidies lead to resource misallocation. Similarly, the influence of tax incentives on R&D investment remains ambiguous (Cowling, 2016; Kobayashi, 2014). This study adds to the literature by comparing the efficacy of direct subsidies and tax incentives.

2.0 Literature Review and Hypotheses

2.1 Effect of Government Research and Development Subsidies on Firm Performance

Existing research has yet to reach a clear consensus on the influence of government R&D subsidies on firm performance. Guo et al. (2016) suggest that subsidies, as a direct form of government support, enhance innovation outputs among SMEs in China. Similarly, Lin and Xie (2023) find that R&D subsidies stimulate technological innovation in green energy firms by influencing their R&D investment intensity. Zhang and Zhang (2023) further reveal that the positive effects of government subsidies on technological innovation are evident only in firms specializing exclusively in either renewable energy or fossil fuels but not in mixed-specialization firms. These mixed findings may stem from firms' diverse innovation objectives and managerial characteristics. Additionally, R&D subsidies may lead to unintended consequences, such as rent-seeking and inefficient investment, as firms might divert resources toward fostering government connections or increase employment artificially to boost local employment (Yu et al., 2010). More recently, studies have found that subsidies negatively affect the financial performance of new energy vehicle firms (categorized as high-tech firms) in China, plausibly due to a lack of demand for their innovation products (Wang et al., 2021). Yu et al. (2020) also find a positive U-shaped relationship between direct subsidies and the financial performance of new energy vehicle firms, suggesting that direct subsidies reduce firms' innovative capability and performance before the subsidies reach a certain level.

The mixed results pertaining to the efficacy of the R&D subsidy policy can be attributable to the varying applicability of R&D subsidies across industries. Generally, high-tech industries have a greater need for government subsidies due to high technological barriers, long innovation cycles, substantial upfront costs, and high failure rates. R&D subsidy policies require a longer period to yield favourable impacts on firm performance. This also explains why some studies, including Wang et al. (2021) and Yu et al. (2020), document a negative or non-linear effect of subsidies on Chinese high-tech firms' performance. In contrast, R&D in traditional industries mostly focuses on production processes and cost control and is less innovation-driven, thus general firms that receive R&D subsidies show improved financial performance more easily. Hence, studying China's high-tech firms provides new insights into the R&D policy efficacy in high-tech industries, addressing a research gap.

Additionally, while there are existing studies on the effects of China's R&D subsidies on firm performance, another crucial fiscal policy instrument, specifically tax incentives, has often been disregarded. Direct subsidies serve as ex-ante government support for R&D projects with high technological risks and high costs by alleviating the financial pressure on firms, whereas tax incentives are ex-post government support that entitles firms that undertake R&D investment to tax reduction or exemption, which commonly include the additional deduction of R&D expenses and corporate income tax exemption (Huang & Hu, 2023). Given the long-term and high-risk nature of R&D, firms receiving direct subsidies often reduce self-financed R&D activities, which lowers total R&D expenditures and diminishes the effectiveness of tax incentives (Wallsten, 2000). Further, only firms with promising R&D projects and strong innovation capabilities are granted direct subsidies through multiple rounds of competition with other firms (Yu et al., 2020). These firms must comply with the disciplinary and monitoring mechanisms imposed by the government to ensure that subsidy funds are used optimally for R&D. Thus, direct subsidies are more effective than tax incentives in promoting firms' R&D. Using a meta-regression analysis, Dimos et al. (2022) reported that the impacts of subsidies on private R&D have increased over time, whereas the effects of tax credits have remained unchanged. This suggests that tax credits are more effective when implemented as 'incremental' schemes. Recognizing this distinction, this study exclusively examines the effects of direct subsidies and tax incentives. Based on the intended positive impact of R&D subsidies, the following hypotheses are proposed:

Hypothesis 1a: Government R&D direct subsidies positively affect firm performance.

Hypothesis 1b: Government R&D tax incentives positively affect firm performance.

2.2 Effect of Government Research and Development Subsidies on Research and Development Investment

R&D investment is a resource-intensive and risky endeavour for firms, mainly due to the uncertain outcomes of innovation (Patel & Chrisman, 2014). Research has shown that R&D subsidies not only help reduce the cost of R&D for firms but also mitigate the risks and uncertainties associated with innovation activities (Akcigit & Kerr, 2018). This, in turn, encourages firms to undertake R&D projects and boosts their overall investment in R&D (Lee, 2011; Wang et al., 2017). Kang and Park (2012) discovered that government support and subsidies for innovation help reduce innovation costs for Korean biotechnology SMEs. Similarly, Carboni (2011) found that R&D subsidies encourage private R&D investment among Italian manufacturing firms, making them more willing to bear the risks associated with R&D. Bronzini and Piselli (2016) also showed that R&D subsidies lead to increased R&D investment, particularly among small firms. Holt et al. (2021) discovered that Australia’s R&D tax policy encourages firms to boost private R&D investments. Similarly, Taş and Erdil (2024) found that R&D tax incentives positively influence firms’ R&D intensity in Turkey. In China, Xu et al. (2021) reported that government R&D subsidies significantly promote R&D investment, enhancing the innovation performance of pharmaceutical companies. Shao et al. (2021) observed that R&D subsidies motivate new energy vehicle firms in China to expand their R&D activities, though the marginal effect diminishes as subsidy intensity rises. Liu and Bai (2021) concluded that while direct subsidies significantly enhance regional innovation efficiency in China, pretax additional deductions do not have a notable impact, suggesting that direct subsidies are more effective than tax incentives.

Conversely, some studies have indicated that R&D subsidies initially boost the R&D expenditures of firms in OECD countries, but eventually lead to a crowding-out effect on self-financed R&D due to the uncertain longevity of government support (Görg & Strobl, 2007; Guellec & Van Pottelsberghe De La Potterie, 2003). A similar substitution effect of government R&D support has been observed among French firms (Marino et al., 2016). Dai and Chapman (2022) found that China's high- and new-technology enterprise tax incentive program increases firms' innovation output but also crowds out their R&D investment. These findings suggest that while R&D subsidies can act as a catalyst for stimulating private R&D investment, their effectiveness also depends on a firm's managerial priorities and resource allocation strategies. Since existing studies generally find that R&D subsidies significantly increase firms' R&D investment, this study hypothesizes that:

Hypothesis 2a: Government R&D direct subsidies positively affect firms' R&D investments.

Hypothesis 2b: Government R&D tax incentives positively affect firms' R&D investments.

2.3 Mediating Effect of Research and Development Investment

Since the 1980s, numerous studies have explored the impact of R&D activities on maintaining a competitive advantage (Pakes & Griliches, 1980; Brenner & Rushton, 1989; Morbey & Reithner, 1990). Generally, R&D investment promotes innovation and new product development, which, in turn, boosts firm productivity (Mansfield, 1986; Griliches, 1986; James & McGuire, 2016). A similar positive relationship between R&D investment and firm performance has been observed globally (Bond & Guceri, 2017; Del Monte & Papagni, 2003; Eberhart et al., 2004; Gunday et al., 2011; Yeh et al., 2010; Zhu & Huang, 2012). Based on this theoretical framework, R&D subsidies can influence firm performance indirectly through the mediating role of R&D investment. Firms that benefit from fiscal subsidies and tax incentives are more inclined to prioritize innovation and increase their R&D spending, which ultimately impacts their performance. Therefore, a mediation analysis is necessary to examine how R&D subsidies affect firm performance through R&D investment.

Some recent studies have highlighted the mediating role of R&D investment. For example, Jia and Wang (2019) analysed data from high-tech firms in China and found that R&D investment mediates the relationship between direct subsidies or tax incentives and innovation performance. In addition, Chen and Liu (2019) explored the mediating role of firm innovation in the connection between government subsidies and development quality, showing that innovation helps mitigate the negative effects of subsidies on development quality and forsters improvements through innovation. At the same time, Zhang et al. (2024) discovered that government subsidies foster the performance of Chinese seed firms through R&D investment, while tax incentives have a direct effect on firm performance. However, there is limited evidence on the mediating role of R&D investment in the relationship between R&D subsidies and the performance of high-tech firms in China. Since both direct subsidies and tax incentives are government-driven measures designed to promote innovation, their effects on firm performance can be indirect, mediated through R&D investment. Thus, the following hypotheses are developed:

Hypothesis 3a: Government R&D direct subsidies enhance firm performance by increasing R&D investment.

Hypothesis 3b: Government R&D tax incentives enhance firm performance by increasing R&D investment.

Figure 3 illustrates the theoretical framework outlining the interrelationships between government R&D subsidies, R&D investment, and firm performance.

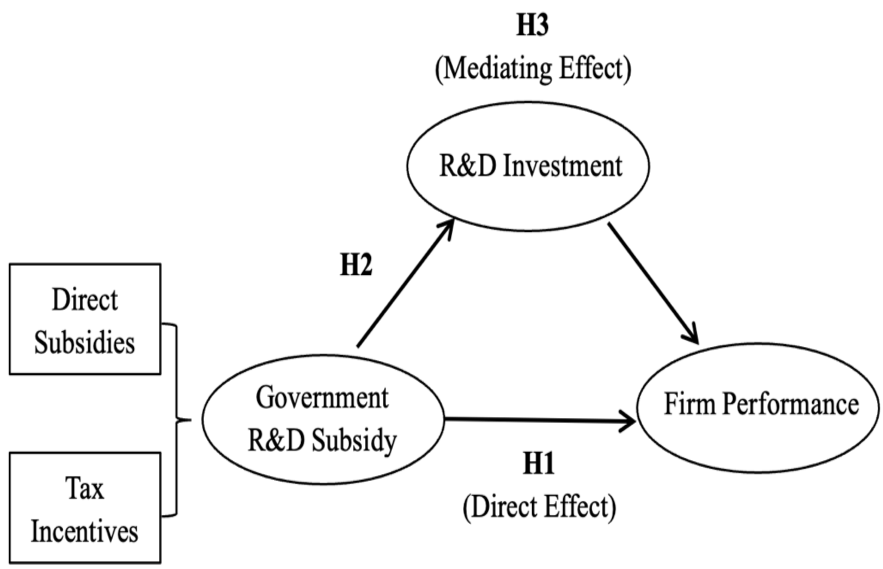

Figure 3: Theoretical Framework

3.0 Methodology

3.1 Sample and Data

The study sample comprises high-tech firms listed on the A-Share Indexes and the Growth Enterprise Board of the Shanghai and Shenzhen stock exchanges. These firms were selected from eight high-tech sectors classified in the Chinese government document *Measures for the Administration of High-tech Enterprise Accreditation*, specifically: electronic information, biotechnology and new medicine, aerospace, new materials, high-tech services, new energy and energy conservation, resources and the environment, advanced manufacturing, and automation. Under the joint collaboration of the Ministry of Science and Technology, the Ministry of Finance, and the State Taxation Administration, these high-tech sectors enjoy various benefits, including tax reductions, funding support, enhanced brand recognition, and talent acquisition. Compared with other industries, high-tech firms are the key beneficiaries of state-supported R&D initiatives, making them a suitable target for assessing the efficacy of government R&D support schemes at the core of China's modernization drive.

Firm data are sourced from the CSMAR database. As R&D expenditure data disclosure began in 2018 and the data for 2022 had not been released at the time of this research, the study period spans from 2018 to 2021. The sample excludes firm-year observations with special treatment (ST) due to abnormal financial conditions, as well as those with incomplete data. The final sample comprises 3,092 firm-year observations from 773 companies.

3.2 Variable Measurement

3.2.1 Firm Performance

Existing literature generally measures firm performance using market-based Tobin's Q and accounting-based profitability. Tobin's Q is calculated as the ratio of a firm's market value — including equity and liabilities —to its total book value of assets (Demsetz & Lehn, 1985). It reflects the market's reaction to news related to the firm. In contrast, profitability is typically indicated by return on assets (*ROA*) and return on equity (*ROE*), which assess a firm's performance based on its accounting records. The market value used in calculating Tobin's Q can be affected by noise traders (Guo et al., 2018; Morck et al., 2000) and political interference (Brunnermeier et al., 2017), which are common in the Chinese stock market context. Due to its vulnerability to irrational trading and macroeconomic shocks, Tobin's Q may not reliably reflect investor confidence in a company's future prospects. Therefore, this study uses accounting-based performance measures, specifically ROA and ROE, to evaluate a firm's profitability and efficiency, offering a more comprehensive assessment of its internal performance.

3.2.2 Research and Development Investment

R&D investment intensity (*RDI*) is calculated as the ratio of a firm's R&D expenditure to its total sales, following prior studies such as Cohen and Levinthal (1990), Kim et al. (2008), and Alessandri and Pattit (2014). As a relative measure, *RDI* is effective for comparing firms within the same industry and tracking a firm's performance over time (Hall & Bagchi-Sen, 2007). Compared to absolute R&D investment values, RDI better reflects a firm's commitment to knowledge creation (Ayaydin & Karaaslan, 2014).

3.2.3 Government Research and Development Subsidy

To measure the extent of direct R&D subsidies received by firms (*D*), this study uses the ratio of direct R&D subsidies to net sales. Direct subsidies for high-tech firms include national funds, provincial funds, individual science and technology funds, and other types of financial support. For measuring R&D tax incentives (*T*), previous studies have primarily relied on two indicators: the nominal income tax rate and the actual income tax rate. Given data availability, quality, and the specific corporate income tax incentives applicable to the high-tech firms in this study, the actual income tax rate is used as the measure of R&D tax incentives.

3.2.4 Control Variables

This study further controls for important firm-specific and macroeconomic factors that may influence firm performance. These include firm size (*SIZE*), leverage (*LEV*), sales growth (*SAL*), economic growth rate (*GDP*), and government expenditure (*LGE*). A summary of all variables is provided in Table 1.

Firm size (*SIZE*) is included to control for the potential effects of economies and diseconomies of scale on firm performance (Alam et al., 2019; Anton, 2019). Larger firms typically have greater capital for R&D investment and more resources, with formalized procedures and efficient operations that support innovation (Majumdar, 1997). As a result, firm size is expected to positively affect firm performance. *SIZE* is measured as the natural logarithm of total assets. Leverage (*LEV*) is used as a proxy for firm risk, calculated as the ratio of total liabilities to total assets. Higher leverage suggests greater difficulty in securing borrowings and loans. Increased debt is associated with higher agency costs and potential underinvestment problems, which can negatively impact firm performance (Ibhagui & Olokoyo, 2018; Lazăr, 2016). Thus, a negative link between leverage and firm performance is anticipated. Sales growth (*SAL*) is measured by a firm's annual sales growth (Alam et al., 2019; Anton, 2019). Growing sales motivate managers, help retain talent, and are often linked to expanding profit margins (Brush et al., 2000). Additionally, sales growth enhances market power, which can further improve performance. Hence, a positive relationship between sales growth and firm performance is anticipated.

Table 1: Variable Definitions

Variable name	Definition	Measurement
ROA	Firm Performance	EBIT/total assets
ROE	Firm Performance	EBIT/total equity
RDI	R&D Intensity	R&D expenditure/net sales
D	Direct Subsidy	Direct subsidy/net sales
T	Tax Incentives	Income tax expense/profit before tax
SIZE	Firm Size	Natural logarithm of total assets
LEV	Leverage	Total liabilities/total assets
SAL	Sales Growth	Yearly change in sales revenue
GDP	GDP Growth	Yearly change in GDP
LGE	Government Expenditure	Natural logarithm of government expenditure

Economic growth (*GDP*) is measured by the annual percentage change in real GDP, reflecting the pace of China's overall economic expansion. GDP growth serves as a key indicator of macroeconomic conditions and can impact firm performance. Government expenditure (*LGE*) is defined as total government spending in the economy and is an important indicator of macroeconomic conditions (Barro & Grilli, 1994). Government spending can significantly shape the business environment and overall economic conditions, therefore affecting firm performance. Before estimation, *LGE* is transformed using the natural logarithm.

3.3 Regression Models

This study conducts a mediation analysis to test the proposed hypotheses. The most popular and well-established framework for examining mediation is the causal-steps approach of Baron and Kenny (1986) (see Figure 4). Mediation analysis primarily examines the product of the coefficients of the explanatory variable and the mediating variable. Various statistical methods exist for testing mediation effects, including the original sequential approach and the Sobel test (MacKinnon et al., 2004). However, the Sobel test has limitations, as it assumes that the product of coefficients follows a normal distribution (Hayes, 2009; MacKinnon et al., 2004). To address these limitations, Wen et al. (2004) developed a process for analysing mediating effects, which facilitates the application of mediation analysis in diverse fields. This method integrates the benefits of the sequential test and the Bootstrap technique. It is recommended to first perform a sequential test for coefficients. If the estimated coefficients are not significant, the product of the coefficients should be directly tested using the Bootstrap method. This approach improves the interpretation of results, helps control Type I error rates, and enhances test power.

Based on Baron and Kenny’s (1986) framework for mediating effects and Wen et al.’s (2004) estimation method, this study develops the following three sets of equations to evaluate the mediating effect of *RDI* on the relationship between government R&D subsidies (*D* and *T*) and firm performance (*ROA* and *ROE*).

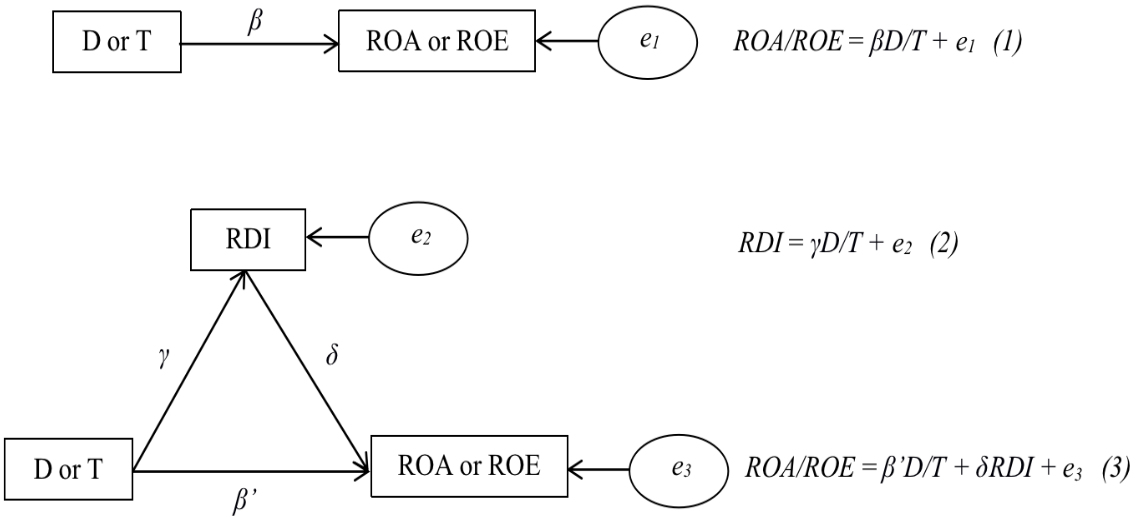

Figure 4: Basic Mediating Effect Model

(1) Effect of government subsidy on firm performance

$$ROA_{it}=\beta_0+\beta_1 D_{it}+\beta_2 SIZE_{it}+\beta_3 LEV_{it}+\beta_4 SAL_{it}+\beta_5 GDP_{it}+\beta_6 LGE_{it}+i+\varepsilon_{it} \quad (1)$$

$$ROE_{it}=\beta_0+\beta_1 D_{it}+\beta_2 SIZE_{it}+\beta_3 LEV_{it}+\beta_4 SAL_{it}+\beta_5 GDP_{it}+\beta_6 LGE_{it}+i+\varepsilon_{it} \quad (2)$$

$$ROA_{it}=\beta_0+\beta_1 T_{it}+\beta_2 SIZE_{it}+\beta_3 LEV_{it}+\beta_4 SAL_{it}+\beta_5 GDP_{it}+\beta_6 LGE_{it}+i+\varepsilon_{it} \quad (3)$$

$$ROE_{it}=\beta_0+\beta_1 T_{it}+\beta_2 SIZE_{it}+\beta_3 LEV_{it}+\beta_4 SAL_{it}+\beta_5 GDP_{it}+\beta_6 LGE_{it}+i+\varepsilon_{it} \quad (4)$$

(2) Effect of government subsidy on R&D investment

$$RDI_{it}=\gamma_0+\gamma_1 D_{it}+\gamma_2 SIZE_{it}+\gamma_3 LEV_{it}+\gamma_3 SAL_{it}+\gamma_5 GDP_{it}+\gamma_6 LGE_{it}+i+\varepsilon_{it} \quad (5)$$

$$RDI_{it}=\gamma_0+\gamma_1 T_{it}+\gamma_2 SIZE_{it}+\gamma_3 LEV_{it}+\gamma_3 SAL_{it}+\gamma_5 GDP_{it}+\gamma_6 LGE_{it}+i+\varepsilon_{it} \quad (6)$$

(3) Mediating effect of R&D investment

$$ROA_{it}=\delta_0+\delta_1 D_{it}+\delta_2 RDI_{it}+\delta_3 SIZE_{it}+\delta_4 LEV_{it}+\delta_5 SAL_{it}+\delta_6 GDP_{it}+\delta_7 LGE_{it}+i+\varepsilon_{it} \quad (7)$$

$$ROE_{it}=\delta_0+\delta_1 D_{it}+\delta_2 RDI_{it}+\delta_3 SIZE_{it}+\delta_4 LEV_{it}+\delta_5 SAL_{it}+\delta_6 GDP_{it}+\delta_7 LGE_{it}+i+\varepsilon_{it} \quad (8)$$

$$ROA_{it}=\delta_0+\delta_1 T_{it}+\delta_2 RDI_{it}+\delta_3 SIZE_{it}+\delta_4 LEV_{it}+\delta_5 SAL_{it}+\delta_6 GDP_{it}+\delta_7 LGE_{it}+i+\varepsilon_{it} \quad (9)$$

$$ROE_{it}=\delta_0+\delta_1 T_{it}+\delta_2 RDI_{it}+\delta_3 SIZE_{it}+\delta_4 LEV_{it}+\delta_5 SAL_{it}+\delta_6 GDP_{it}+\delta_7 LGE_{it}+i+\varepsilon_{it} \quad (10)$$

Where i is a specific firm, t is a specific year. α_0 represents the constant term. β_0, γ_0, and δ_0 represent the constant term. β_i, γ_i, and δ_i represent the coefficients of a specific explanatory variable, and ε_{it} is the random disturbance term. Firm fixed-effects (i) are also controlled to alleviate omission bias induced by unobserved firm-specific factors.

The estimation process is summarized in three steps. The first step involves estimating *Eq.(1)* to *Eq.(4)* to determine the total effect of R&D subsidies on firm performance: β denotes the coefficient of *D* or *T* in *ROA* or *ROE* regression (when the mediating variable is excluded from the model). If β_1 is significant, regardless of the sign, it indicates a significant effect of R&D subsidies. Notably, the actual income tax rate (*T*), which represents the government's R&D tax incentives, serves as an inverse indicator. Thus, a significantly negative β_1 in *Eqs. (3)-(4)* indicates that R&D tax incentives significantly improve firm performance.

The second step examines the significance of the indirect effects of *D* and *T*, which are indicated by coefficients γ_1 and δ_2. γ_1 denotes the coefficient of *D* or *T* in the RDI regression specified by *Eq.(5)* and *Eq.(6)*. δ_2 denotes the coefficient of the mediating variable *RDI* in the *ROA* or *ROE* regression specified in *Eq.(7)* to *Eq.(10)*. If both coefficients are significant, indicating a significant indirect effect of *D* or *T* on firm performance, the analysis proceeds to the third step. If at least one of the two is insignificant, the Bootstrap method should be used to test the significance of $\gamma_1*\delta_2$ directly. If $\gamma_1*\delta_2$ is statistically significant, then the mediating effect of *RDI* is evident, and the next step is conducted. Conversely, if $\gamma_1*\delta_2$ is insignificant, then the mediating effect of *RDI* is absent.

The third step tests the significance of the direct effects of *D* and *T* by estimating the coefficient δ_1 in *Eq.(7)* to *Eq.(10)* which considers the mediating variable *RDI*. If δ_1 is insignificant, suggesting no direct effect of *D* or *T*, this study concludes that the effect of *D* or *T* on firm performance occurs exclusively through the mediating role of *RDI*. If δ_1 is significant, which implies a significant direct effect of *D* or *T*, then the signs of $\gamma_1 * \delta_2$ and δ_1 need to be further compared. If the signs are the same, a partial mediating effect is observed; otherwise, a suppressing effect is observed. It is also important to note that the significantly negative δ_1 in *Eq.(9)* and *Eq.(10)* represents a positive effect of *T* as *T* in an inverse proxy for R&D tax incentives. The entire process of mediating effect analysis is shown in Figure 5, and the Bootstrap method is performed using SPAUSS.

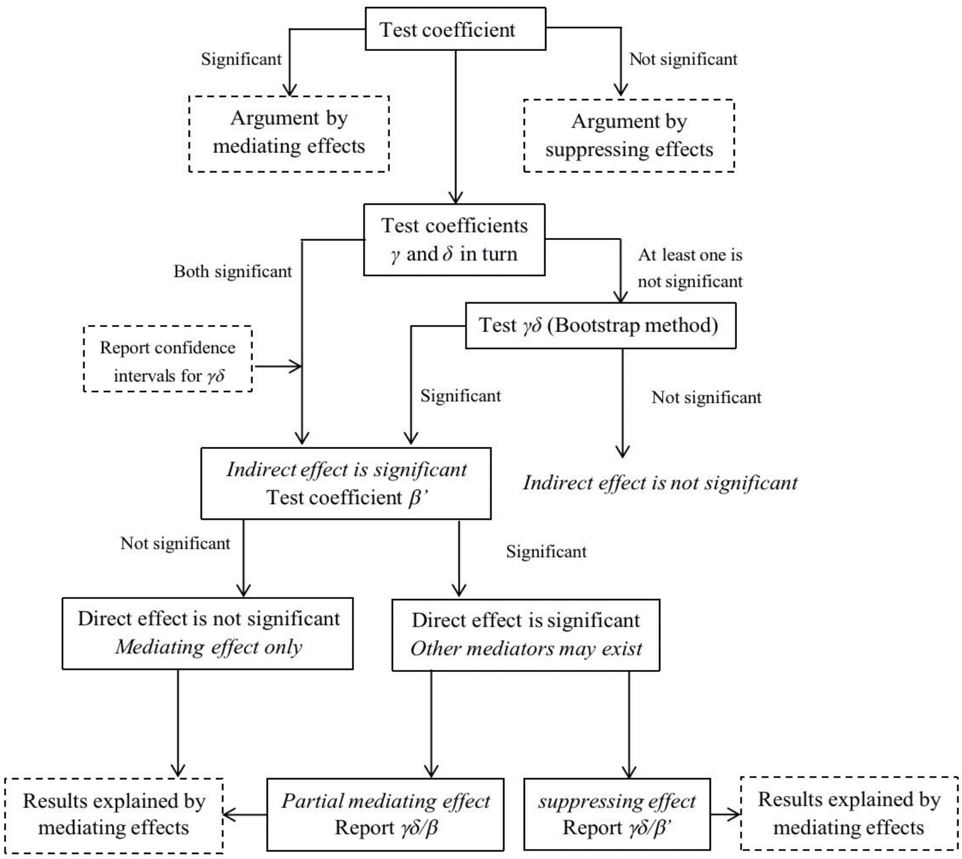

Figure 5: Process of Mediating Effect Analysis

4.0 Results and Discussion

4.1 Descriptive Statistics

Table 2 provides the descriptive statistics for the variables. The mean values of *ROA* and *ROE* are 0.0336 and 0.0310, respectively, indicating that the average profitability of high-tech firms is relatively low. The range of *ROA* spans from -1.2401 to 0.4234, while *ROE* ranges from -12.9144 to 0.0578, showing substantial differences in profitability among the listed firms. These variations likely stem from diverse business goals and strategies. The average *RDI* is 7.64%, with a median value of 5.66%. According to Chen and Miller (2007), firms with an R&D investment intensity exceeding 5% are considered to have a competitive advantage, suggesting that these high-tech firms possess significant market advantages. The mean values for direct subsidies and tax incentives are 0.0189 and -0.0384, respectively. Regarding control variables, such as firm size, leverage, sales growth, GDP growth rate, and government expenditures, have mean values of 9.6015, 0.4057, 0.3580, 0.0848, and 12.3782, respectively. The standard deviations for these control variables, except for sales growth are relatively small, except for sales growth, which exhibits a high standard deviation of 2.93. This suggests considerable variation in sales growth among firms over time.

Table 2: Descriptive Statistics

Variables	Mean	Median	Maximum	Minimum	Std. Dev.
ROA	0.0336	0.0418	0.4234	-1.2401	0.0990
ROE	0.0310	0.0672	0.0578	-12.9144	0.3906
RDI	0.0764	0.0566	0.6204	0.0003	0.0640
D	0.0189	0.0113	1.1577	-0.0001	0.0364
T	-0.0384	0.1113	8.7944	-230.1404	4.5629
SIZE	9.6015	9.5469	11.7733	8.4814	0.4953
SAL	0.4057	0.0932	94.1313	-0.9990	2.9343
LEV	0.3580	0.3433	0.9845	0.0143	0.1731
GDP	0.0848	0.0890	0.1339	0.0274	0.0395
LGE	12.3782	12.3977	12.4118	12.3055	0.0435

4.2 Correlation

Table 3 presents that the highest absolute value of the correlation coefficient among explanatory variables is 0.35, suggesting no severe multicollinearity issue. Table 4 shows that the Variance Inflation Factor (VIF) values for all the explanatory variables are as low as approximately 1.00. This is far below the benchmark of 10 suggested by Neter et al. (2004), affirming the absence of multicollinearity.

Table 3: Correlation Matrix

	ROA	*ROE*	*RDI*	*T*	*D*	*SIZE*	*LEV*	*SAL*	*GDP*	*LGE*
ROA	1.00									
ROE	-0.66	1.00								
RDI	-0.04	-0.03	1.00							
T	0.02	0.01	0.01	1.00						
D	-0.01	0.00	0.29	0.00	1.00					
SIZE	0.08	0.08	-0.15	0.02	-0.03	1.00				
LEV	-0.29	-0.20	-0.24	-0.02	-0.08	0.35	1.00			
SAL	-0.01	-0.04	0.00	0.00	0.00	0.00	0.01	1.00		
GDP	0.00	-0.01	0.00	-0.02	-0.03	0.01	0.00	-0.02	1.00	
LGE	-0.03	-0.24	0.06	0.03	-0.02	0.08	0.05	0.00	-0.26	1.00

Table 4: VIF and 1/VIF Measures

Variable	VIF	1/VIF
D	1.09	0.9138
T	1.00	0.9978
RDI	1.17	0.8572
LEV	1.19	0.8383
SIZE	1.15	0.8674
LGE	1.09	0.9136
GDP	1.08	0.9269
SAL	1.00	0.9993

4.3 Regression Results and Discussion

Table 5 to 8 present the results of the mediating effect analysis. The first step of the analysis involves estimating the total effects of R&D subsidy based on *Eq.(1)* to *Eq.(4)*. Column (1) of Tables 5-8 shows that the coefficient β_1 for *D* and *T* is not significant. Hence, Hypotheses 1a and 1b are not supported, indicating that neither direct subsidies nor tax incentives have a significant effect on high-tech firm performance.

Columns (2) and (3) of Tables 5-6 show the estimation results for *Eq. (5)*, *Eq. (7)* and *Eq. (8)* in accordance with the second and third steps of the analysis. The results indicate a significantly positive coefficient of *D* (γ_1) in column (2), supporting Hypothesis 2a that direct subsidies stimulate firms' R&D investments. Furthermore, the estimate of *D* (δ_1) in column (3) is insignificant, implying that the direct effect of direct subsidies on firm performance is insignificant.

This study also applies the bootstrap method to compute a 95% confidence interval for $\gamma_1 * \delta_2$ and reports the results in Table 9. It is noted that the 95% confidence interval of $\gamma_1 * \delta_2$ is (-0.046 ~ -0.015) in *ROA* regression, and (-0.038 ~ -0.012) in *ROE* regression. Since the confidence interval does not include zero, this study concludes that R&D investment negatively mediates the effect of direct subsidies on firm performance. This indicates that direct subsidies reduce firm performance by encouraging R&D investment, leading to the rejection of Hypothesis 3a. This result aligns with Wang et al. (2021), who found that R&D subsidies reduce high-tech firm performance, as increased R&D may not always yield positive returns due to high failure rates and the slow market adoption of emerging technological products.

In Tables 7 and 8, the coefficient of *T* (γ_1) is insignificant in both columns (2) and (3), while the coefficient on *RDI* (δ_2) is significant in column (3). The insignificant coefficient of *T* suggests that tax incentives do not affect firm performance even after controlling for R&D investment. This study further applies the bootstrap method to test the significance of $\gamma_1 * \delta_2$. The results in Table 9 show that the 95% confidence interval for $\gamma_1 * \delta_2$ is (-0.002 ~ 0.005) for both *ROA* and *ROE*. Since the confidence interval contains zero, implying an insignificant estimate of $\gamma_1 * \delta_2$, this study concludes that there is no mediating effect of R&D investment. Hypothesis 3b is thus not supported.

In summary, the results in Tables 5-8 indicate that neither government R&D direct subsidies nor tax incentives significantly enhance firm performance. There are several possible explanations for these findings. First, fiscal funds and tax reductions aimed at supporting firms' R&D activities are often a one-time intervention without continuity, meaning that government support can only help high-tech firms overcome short-term capital shortages. However, for most high-tech firms, the lengthy R&D cycle leaves them facing a persistent lack of funding. As a result, the long-term impact of R&D subsidies on firm performance may be minimal. Second, consistent with some prior studies, government subsidies may crowd out firms' private R&D expenditures, leading to no net increase in total R&D investments (Marino et al., 2016; Shrieves, 1978; Wallsten, 2000).

Moreover, this study finds that while direct subsidies significantly increase firms' R&D investment, tax incentives have no similar effect. This supports Liu and Bai (2021) and Yu et al. (2020), who argue that direct R&D subsidies are a more effective means of encouraging Chinese firms to increase R&D investment, as they provide ex-ante support. Firms receiving government R&D subsidies must also adhere to strict guidelines on fund usage, fostering stronger discipline and commitment to R&D. Further, firms may have an incomplete understanding of various government tax incentives, making them less influential in R&D decision-making. Similarly, Yigitcanlar et al. (2019) report comparable findings for Australia and Brazil. Although the R&D tax incentive scheme is the most popular in these countries, its positive impact on firm technological innovation remains marginal. Two key reasons for this are firms' lack of awareness of the scheme and the limited accessibility of incentives for firms located outside 'technology cluster areas' due to informational transparency issues.

This study also reveals that R&D investment fully mediates the link between direct subsidies and firm performance. However, its mediating effect on the relationship between tax incentives and firm performance is insignificant. This outcome highlights the different characteristics of these two types of government R&D subsidies. Direct subsidies are provided by the government prior to R&D activities and align with various national policy objectives. They are specifically intended to fund R&D and innovation projects, making them more direct and legally binding, and thus more effective in stimulating R&D (Yu et al., 2020). In contrast, tax incentives are indirect subsidies that are granted after R&D activities have been completed. These incentives are typically smaller in scale than direct subsidies, which makes their mediating effect on firm performance less pronounced compared to direct subsidies (Liu & Bai, 2021).

Pertaining to the effects of control variables, the results in Table 5 to Table 8, columns (1) and (3), are mostly consistent, regardless of the firm performance measures (*ROA* and *ROE*) and the government subsidy measures (*D* and *T*). Specifically, the coefficient of *SIZE* is positive and statistically significant, suggesting that larger firms are more profitable. This can be attributed to the existence of economies of scale in large firms and their greater capability to leverage capital, talent, and assets in business operations, thereby yielding greater returns (Majumdar, 1997). The coefficient of *LEV* is significantly negative, suggesting that firm leverage has a significantly negative effect on firm performance. This finding aligns with Asimakopoulos et al. (2009), who argue that high leverage increases the costs of debt and the risk of bankruptcy. The coefficient of *SAL* is insignificant, suggesting that sales growth does not translate to increased firm profitability, possibly due to the high operating costs of high-tech firms.

Additionally, the coefficients of *GDP* and *LGE* are negative and significant in most models, indicating that economic growth and government fiscal expenditure negatively influence the performance of high-tech firms. The study period spans significant events such as the supply-side structural reform, the US-China trade war, and the Covid-19 pandemic. These events introduced substantial economic uncertainties, business shutdowns, economic slowdowns, and cuts in fiscal expenditures in China. As most high-tech firms operate in essential sectors such as biotechnology and pharmaceuticals, electronic information, resources and the environment, and are government-supported, they hold competitive and strategic advantages over general firms. As a result, these firms continue to grow and even receive new business opportunities during downturns (Hossain et al., 2023).

Table 5: Mediating Analysis Results of *D* with Dependent Variable *ROA*

	(1) *ROA*		(2) *RDI*		(3) *ROA*	
	β	*t*-statistics	*γ*	*t*-statistics	*δ*	*t*-statistics
D	0.006	0.116	0.475***	16.160	0.001	0.211
RDI					-0.159***	-5.656
SIZE	0.144***	8.273	-0.046***	-8.519	0.041***	11.302
LEV	-0.396***	-15.781	-0.074***	-0.022	-0.218***	-20.835
SAL	0.000	0.372	0.000	0.489	0.000	0.646
GDP	-0.065*	-1.715	0.047***	3.956	-0.026***	-0.600
LGE	-0.137***	-3.578	0.148***	12.366	-0.049***	-1.223
Constant	0.497	1.182	-1.316***	-10.020	0.340***	0.690
Firm-fixed effect	yes	yes	yes	yes	yes	yes
N	3,092	3,092	3,092	3,092	3,092	3,092

Note: This table shows the estimation results of Eqs. (1), (5) and (7). *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 6: Mediating Analysis Results of *D* with Dependent Variable *ROE*

	(1) *ROE*		(2) *RDI*		(3) *ROE*	
	β	*t*-statistics	*γ*	*t*-statistics	*δ*	*t*-statistics
D	-0.087	-0.361	0.475***	16.16	0.030	0.156
RDI					-0.465***	-4.066
SIZE	0.581***	7.585	-0.046***	-8.519	0.130***	8.885
LEV	-1.755***	-15.850	-0.074***	-0.022	-0.625***	-14.641
SAL	-0.003**	-1.409	0.000	0.489	-0.005***	-1.952
GDP	-0.297*	-1.788	0.047***	3.956	-0.152	-0.856
LGE	-0.508***	-3.008	0.148***	12.366	-0.211	-1.298
Constant	1.399	0.754	-1.316***	-10.020	1.669	0.830
Firm-fixed effect	yes	yes	yes	yes	yes	yes
N	3,092	3,092	3,092	3,092	3,092	3,092

Note: This table shows the estimation results of Eqs. (2), (5) and (8). *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics is reported in parenthesis.

Table 7: Mediating Analysis Results of *T* with Dependent Variable *ROA*

	(1) *ROA*		(2) *RDI*		(3) *ROA*	
	β	*t*-statistics	*γ*	*t*-statistics	*δ*	*t*-statistics
T	0.004	1.269	0.001	0.301	0.001	0.398
RDI					-0.160***	-5.954
SIZE	0.143***	8.268	-0.010***	-4.077	0.041***	11.287
LEV	-0.396***	-15.800	-0.082***	-11.96	-0.218***	-20.816
SAL	0.000	0.371	0.000	0.405	0.000	-0.46
GDP	-0.064*	-1.698	0.032	1.094	-0.025	-0.584
LGE	-0.138***	-3.608	0.123***	4.622	-0.049	-1.221
Constant	0.511	0.420	-1.323***	-4.029	0.339	0.688
Firm-fixed effect	yes	yes	yes	yes	yes	yes
N	3,092	3,092	3,092	3,092	3,092	3,092

Note: This table shows the estimation results of Eqs. (3), (6) and (9). *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 8: Mediating Analysis Results of *T* with Dependent Variable *ROE*

	(1) *ROE*		(2) *RDI*		(3) *ROE*	
	β	*t*-statistics	*γ*	*t*-statistics	*δ*	*t*-statistics
T	0.001	0.564	0.001	0.301	0.001	0.064
RDI					-0.460***	-4.189
SIZE	0.581***	7.583	-0.010***	-4.077	0.130***	8.890
LEV	-1.752***	-15.847	-0.082***	-11.960	-0.626***	-14.642
SAL	-0.003	-1.408	0.000	0.405	-0.005*	-1.953
GDP	-0.292*	-1.761	0.032	1.094	-0.154	-0.865
LGE	-0.508***	-3.008	0.123***	4.622	-0.213	-1.308
Constant	1.394	0.564	-1.323***	-4.029	1.683	0.838
Firm-fixed effect	yes	yes	yes	yes	yes	yes
N	3,092	3,092	3,092	3,092	3,092	3,092

Note: This table shows the estimation results of Eqs. (4), (6) and (10). *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 9: Summary of Mediating Analysis Results

Variables	*β*	*γ*	*δ*	*γ*δ*	95% BootCI	*β'*	Test conclusion
D=>RDI=>ROA	0.006	0.475***	-0.159***	-0.075	-0.046 ~ -0.015	0.001	Complete mediating effect
D=>RDI=>ROE	-0.087	0.475***	-0.465***	-0.221	-0.038 ~ -0.012	0.03	Complete mediating effect
T=>RDI=>ROA	0.004	0.001	-0.160***	0	-0.002 ~ 0.005	0.001	Mediating effect is not significant
T=>RDI=>ROE	0.001	0.001	-0.460***	0	-0.002 ~ 0.005	0.001	Mediating effect is not significant

Note: *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively.

4.4 Robustness and Additional Analyses

4.4.1 Addressing Reverse Causation

A reverse causation may arise between *RDI* and firm performance (*ROA* and *ROE*) because firm performance generates the capital needed for R&D efforts (Lai et al., 2015). As a result, firm performance may reversely positively influence firm RDI. To address this issue, this study employs a panel 2SLS-IV approach. This study identifies the one-year lagged firm capital-to-total assets ratio (*l.CAPITAL*) as an instrument for *RDI*, given that R&D is resource-intensive and risky, requiring substantial capital reserves to support firm *RDI* (Lai et al., 2015; Moehrle & Walter, 2008).

Table 10 presents the two-stage results of the 2SLS-IV estimations, with Panel A using *D* and Panel B using *T* as proxies for government subsidies. The statistically significant first-stage *F*-statistics and *l.CAPITAL* coefficient reported in both panels indicates that the instrument for *RDI* is valid. Additionally, *l.CAPITAL* positively affects firm *RDI*, which is as expected. The Cragg-Donald Wald *F*-statistic values exceed the 10% Stock-Yogo critical value (16.38), implying that the instrument is strong. The under-identification test also reports statistically significant χ^2 values, confirming that the first-stage equation is identified and that the instrument is relevant. The second-stage 2SLS-IV regression results in Panels A and B show that instrumented *RDI* has a significant negative effect on both *ROA* and *ROE* models, aligning with the mediation results in Tables 5-8. The estimates for *D* and *T* are also positive but mostly insignificant, affirming reinforcing that these government subsidies influence firm performance only through the mediating role of *RDI*.

4.4.2 Including More Control Variables

This study further alleviates possible omitted variable bias by controlling for additional variables. Prior R&D literature generally finds that property right protects innovators from infringements and reward them for their innovations, thereby encouraging them to engage in research and development activities, which lead to technological innovation and industrial structure upgrading (Cao et al., 2023; Cho & Kim, 2017). Additionally, unobservable macro-level factors may influence the *RDI* and performance of firms. Thus, this study controls for the quality of property rights protection (*PR*) in the country and time-fixed effects in the regression estimations. The annual *PR* data, obtained from the Heritage Foundation (2024), measures the quality of a country's property rights protection laws. *PR* is scaled from 0 (lowest quality) to 100 (highest quality).

Table 11 shows that *PR* indeed promotes the *RDI* of firms (see column (1)), which supports the findings of Cao et al. (2023), and Cho and Kim (2017). More importantly, this study notes that, after controlling for *PR* and time-fixed effects, the positive coefficient of *D* becomes weakly significant in the *ROA* model (see Panel A, column (2)), suggesting that direct subsidies have a mild positive and direct effect on firm performance. Nonetheless, all other results remain similar to the main results.

4.4.3 Possible Influence of Firm Size

One could argue that the ability of high-tech firms to attract public R&D subsidies and private capital, as well as engage in risky R&D investments, may vary according to firm size. Specifically, larger firms benefit from reputational advantages and operational scale and scope, which grant them broader access to capital forR&D investments (Fishman & Rob, 1999; Lai et al., 2015). Larger firms also tend to have a larger workforce that supports their R&D investments (Park et al., 2010). In contrast, capital sources for small firms tend to be more localized and limited, reducing their ability to absorb the risks associated with R&D activities. To investigate whether firm size influences the main findings, this study classifies firms into large and small subsamples using the median of *SIZE* (9.55), then re-performs the regression estimations.

Panels A and B of Table 12 show the results for small and large firms, respectively, using *ROA* as the firm performance measure and *D* as the R&D subsidy proxy. It is noted that *D* does not have a direct impact on *ROA* but affects it indirectly by stimulating firms' *RDI*, which affirms the main results in Table 5. This result is consistent across small and large firms, suggesting that the main results are not sensitive to firm size. For brevity, this paper does not report the regression results using *ROE* as the firm performance measure and *T* as the R&D subsidy proxy; however, this study affirms that the main results hold across both small and large firms.

4.4.4 Short-Term Impact Assessment

Thus far, this study finds that R&D subsidies, in the form of direct subsidies and tax incentives, generally lack a significant direct or total impact on firm performance. As an additional analysis, this study investigates whether direct subsidies (*D*) and tax incentives (*T*) exert short-term impacts on firm performance by regressing firm performance measures on lagged values of *D* and *T*.

Table 13 presents the results using one-year lagged values of *D* and *T* in Panels A and B, respectively. It is found that one-year lagged *D* has a significantly negative coefficient in the *ROA* model. However, when *D* is lagged by two years, it becomes positive and significant in both *ROA* and *ROE* models. These mixed findings suggest that direct subsidies have both substitution and additionality effects on firm performance in the short run. Regarding tax incentives, the coefficient of *L1.T* is positive and significant in both *ROA* and *ROE* models, indicating a short-term positive impact on firm performance. This effect is not evident when *L2.T* is used. Thus, this study concludes that direct subsidies and tax incentives mainly serve as temporary financial aid for high-tech firms to boost their performance. Over-reliance on government R&D subsidies may weaken firms' incentives to self-finance R&D activities, potentially leading to diminished capital-raising capabilities and reduced resilience in sustaining long-term R&D efforts (Marino et al., 2016; Wallsten, 2000).

Table 10: Panel IV-2SLS Estimation Results

Panel A: Effect of *D* on firm performance			
	First-stage *RDI*	Second-stage *ROA*	Second-stage *ROE*
l.CAPITAL	0.065***		
	(6.50)		
D	0.056***	0.338**	0.561
	(2.65)	(2.56)	(1.27)
RDI (instrumented)		-5.913***	-14.776***
		(-6.64)	(-4.96)
Control variables	yes	yes	yes
Firm-fixed effect	yes	yes	yes
First stage *F*-statistic	42.20***		
Second stage *F*-statistic		16.93***	26.21***
Cragg-Donald Wald *F*-statistic	42.195		

Underidentification test LM statistic (χ^2)	41.256***		
N	2,319	2,319	2,319

Panel B: Effect of *T* on firm performance			
	First-stage *RDI*	Second-stage *ROA*	Second-stage *ROE*
l.CAPITAL	0.066***		
	(6.53)		
T	0.0002	0.001	0.003
	(0.74)	(0.93)	(0.56)
RDI (instrumented)		-5.871***	-14.704***
		(-6.67)	(-4.98)
Control variables	yes	yes	Yes
Firm-fixed effect	yes	yes	Yes
First stage *F*-statistic	42.58***		
Second stage *F*-statistic		17.07***	26.21***
Cragg-Donald Wald *F*-statistic	42.577		
Underidentification test LM statistic (χ^2)	41.620***		
N	2,319	2,319	2,319

Note: *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 11: Including More Control Variables

Panel A: Effect of *D* on firm performance			
	(1) *RDI*	(2) *ROA*	(3) *ROE*
D	0.098***	0.092*	0.114
	(2.65)	(1.74)	(0.47)
RDI		-0.885***	-2.12***
		(-13.80)	(-7.27)
PR	0.001***	0.0001	-0.002
	(3.92)	(0.18)	(-0.85)
Other control variables	yes	yes	yes
Firm-fixed effect	yes	yes	yes
Time-fixed effect	yes	yes	yes
N	3,092	3,092	3,092
Panel B: Effect of *T* on firm performance			
	(1) *RDI*	(2) *ROA*	(3) *ROE*
T	0.000002	0.0004	0.001
	(0.02)	(1.31)	(0.55)
RDI		-0.872***	-2.10***
		(-13.68)	(-7.26)
PR	0.001**	0.0001	-0.002
	(3.78)	(0.15)	(-0.86)
Other control variables	yes	yes	yes

Firm-fixed effect	yes	yes	yes
Time-fixed effect	yes	yes	yes
N	3,092	3,092	3,092

Note: *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 12: Influence of Firm Size

Panel A: Small firms			
	(1) *ROA*	(2) *RDI*	(3) *ROA*
D	0.051	0.057**	0.105
	(0.60)	(2.22)	(1.28)
RDI			-0.932***
			(-9.74)
Control variables	yes	yes	yes
Firm-fixed effect	yes	yes	yes
N	1,546	1,546	1,546
Panel B: Large firms			
	(1) *ROA*	(2) *RDI*	(3) *ROA*
D	-0.046	0.117***	0.040
	(-0.70)	(5.38)	(0.62)
RDI			-0.738***
			(-8.25)
Control variables	yes	yes	yes
Firm-fixed effect	yes	yes	yes
N	1,546	1,546	1,546

Note: *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

Table 13: Short-Term Impact Assessment

Panel A: Effect of *D* on firm performance				
	(1) ROA	*(2) ROA*	*(3) ROE*	*(4) ROE*
L1.D	-0.092***		-0.12	
	(-2.79)		(-1.52)	
L2.D		0.113***		0.307**
		(3.37)		(2.02)
Control variables	yes	yes	yes	yes
Firm-fixed effect	yes	yes	yes	yes
N	2,319	1,546	2,319	1,546
Panel B: Effect of *T* on firm performance				
	(1) *ROA*	(2) *ROA*	(3) *ROE*	(4) *ROE*
L1.T	0.0003***		0.001**	

	(5.50)		(2.06)	
L2.T		-0.0001		-0.001
		(-0.52)		(-1.05)
Control variables	yes	yes	yes	yes
Firm-fixed effect	yes	yes	yes	yes
N	2,319	1,546	2,319	1,546

Note: *, **, and *** denote statistical significance at 10%, 5%, and 1%, respectively. *t*-statistics are reported in parentheses.

5.0 Conclusion and Future Research

This study investigates the interrelationships among R&D investment, government R&D subsidies, and firm performance using a balanced panel of 773 listed high-tech firms in China from 2018 to 2021. The key findings are as follows: First, neither direct R&D subsidies nor tax incentives significantly impact firm performance. Second, direct subsidies significantly boost R&D investment, whereas tax incentives do not. Third, R&D investment negatively mediates the relationship between direct subsidies and firm performance but does not mediate the effect of tax incentives on firm performance.

The study findings offer important theoretical implications for the literature. First, the findings challenge the conventional belief that government R&D subsidies directly enhance firm performance. While prior research often assumes a positive influence of subsidies on firm outcomes, this study provides evidence that direct subsidies in high-tech sectors may lead to unintended negative consequences by encouraging resource-intensive and high-risk R&D investments or by crowding out self-financed private R&D investments. This highlights the importance of incorporating risk-based perspectives, such as agency theory and resource-based theory, into discussions on the efficacy of government subsidies in fostering firm development. Second, this study contributes to the debate on the efficacy of different government support types by distinguishing between direct R&D subsidies and tax incentives. Consistent with Yu et al. (2020), *ex-ante* government subsidies are more effective than *ex-post* subsidies in China because the former incorporate disciplinary and monitoring mechanisms by the government to ensure that subsidy funds are used optimally for R&D.

The study results offer numerous implications for policymakers and managers in high-tech industries. Policymakers should consider implementing comprehensive top-level designs and improving tax policies and regulations that align with industry needs to better support the development of the high-tech sector. Prioritizing direct subsidies for R&D can incentivize firms to undertake R&D activities, with tax incentives strategically allocated as complementary measures. Countries like Germany, Canada, Australia, and the United States provide valuable insights through their tax policies, such as pre-tax deductions for R&D expenses and accelerated depreciation for equipment and software. China could consider adopting similar tax incentives to foster the development of its high-tech industry. However, the government needs to ensure transparency in the tax incentive scheme, allowing all high-tech firms to benefit from it effectively.

Furthermore, policymakers should acknowledge that the influence of government subsidies on firm research and innovation capabilities is influenced by various factors, such as the external environment, industry characteristics, and the stage of the industry life cycle. To mitigate the crowding-out effect of excessive dependence on government subsidies, it is important to explore diverse financing channels. Additionally, tax policies should be periodically adjusted to stay in line with changing economic conditions and the evolving needs of enterprises.

High-tech industry managers should actively leverage national R&D tax incentives. After understanding the eligibility criteria, firms should take proactive steps to enhance internal processes, including increasing R&D intensity and upgrading R&D infrastructure. Additionally, managers should optimize the use of direct R&D subsidies. Rather than relying solely on government support, they should raise their own funds and use them as efficiently as public funds. By effectively utilizing tax incentives, refining internal processes, and maximizing subsidies, high-tech firms can significantly boost innovation efficiency and overall competitiveness.

This study has a few limitations that future research could address. First, mediating effect models are frequently used in psychological research, where data often come from controlled experiments rather than real-world strategic responses. Thus, the applicability of the mediating effect model to corporate finance —where decisions are driven by cost-benefit analysis—requires further exploration. Second, this study relies on commonly used measures for R&D subsidies, R&D investment, and firm performance due to data constraints, which may introduce certain limitations. Future research could improve the robustness of results by adopting alternative measurements for these variables. Finally, future research could employ a more comprehensive dataset to improve result accuracy and reliability.

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